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2005 Shellfish Indicator Report

Phil Trowbridge
New Hampshire Department of Environmental Services

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New Hampshire Estuaries Project

Environmental Indicator Report: Shellfish

Prepared by:

Phil Trowbridge
NHEP Coastal Scientist
New Hampshire Department of Environmental Services

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ENVIRONMENTAL INDICATOR REPORT

SHELLFISH

Prepared By

Phil Trowbridge
NHEP Coastal Scientist
New Hampshire Department of Environmental Services
Watershed Management Bureau
Concord, NH 03301

Prepared For

New Hampshire Estuaries Project
University of New Hampshire
Hewitt Annex
54 College Road
Durham, New Hampshire 03824

Jennifer Hunter, Director

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ACKNOWLEDGMENTS

This report was peer-reviewed by the NHEP Technical Advisory Committee. The members of this committee deserve thanks for their time and thoughtful input.

NHEP Technical Advisory Committee (TAC)

NAME	ORGANIZATION
Steve Jones, Chair	UNH
Tom Ballestero	UNH
Jean Brochi	USEPA
Gregg Comstock	NHDES
Paul Currier	NHDES
Ted Diers	NHDES-NHCP
Jennifer Hunter	NHEP
Natalie Landry	NHDES
Richard Langan	CICEET
Chris Nash	NHDES
Jon Pennock	UNH
Fay Rubin	UNH
Fred Short	UNH
Brian Smith	NHF&G
Sally Soule	NHDES-NHCP
Phil Trowbridge	NHDES/NHEP

UNH = University of New Hampshire
USEPA = US Environmental Protection Agency
NHDES = NH Department of Environmental Services
NHCP = NH Coastal Program
CICEET = Cooperative Institute for Coastal and Estuarine Environmental Technology
NHF&G = NH Fish and Game Department

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INTRODUCTION

The New Hampshire Estuaries Project (NHEP) is part of the U.S. Environmental Protection Agency's National Estuary Program, which is a joint local/state/federal program established under the Clean Water Act with the goal of protecting and enhancing nationally significant estuarine resources. The NHEP is funded by the EPA and is administered by the University of New Hampshire.

The NHEP's Comprehensive Conservation and Management Plan for New Hampshire's estuaries was completed in 2000 and implementation is ongoing. The Management Plan outlines key issues related to management of New Hampshire's estuaries and proposes strategies (Action Plans) that are expected to preserve, protect, and enhance the State's estuarine resources. The NHEP's priorities were established by local stakeholders and include water quality improvements, shellfish resources, land protection, and habitat restoration. Projects addressing these priorities are undertaken throughout NH's coastal watershed, which includes 42 communities.

Every three years, the NHEP prepares a State of the Estuaries report with information on the status and trends of a select group of environmental indicators from the coastal watershed and estuaries. The report provides the NHEP, state natural resource managers, local officials, conservation organizations, and the public with information on the effects of management actions and decisions.

Prior to developing each State of the Estuaries report, the NHEP publishes four technical data reports ("indicator reports") that illustrate the status and trends of the complete collection of indicators tracked by the NHEP. Each report focuses on a different suite of indicators: Shellfish, Water Quality, Land Use and Development, and Habitats and Species. All of the indicators are presented to the NHEP Technical Advisory Committee, which selects a subset of indicators to be presented to the NHEP Management Committee and to be included in the State of the Estuaries report. The Management Committee reviews the indicators and finalizes the list to be included in the report. Between 10 and 20 indicators are included in each State of the Estuaries report. The 2005 Shellfish Indicator Report is the second NHEP indicator report for shellfish resources. Data from this report will be used in the 2006 State of the Estuaries report.

The following sections contain the most recent data for the 12 shellfish indicators tracked by the NHEP. In some cases the NHEP funds data collection and monitoring activities; however data for the majority of indicators are provided by other organizations with monitoring programs. The details of the monitoring programs and performance criteria for the indicators are listed in the NHEP Monitoring Plan (NHEP, 2004).

The results and interpretation for the indicators presented in this report have been peer reviewed by the NHEP Technical Advisory Committee and other experts in relevant fields.

SHL1 - AREA OF OYSTER BEDS IN GREAT BAY

Monitoring Objective

The objective of this indicator is to track the areas of the six major oyster beds in Great Bay relative to their areas in 1997. This is directly relevant to management objective "SHL1-3: No net decrease in acreage of oyster beds from 1997 amounts for Nannie's Island, Woodman Point, Piscataqua River, Adams Point, Oyster River, Squamscott River, and Bellamy River beds". The monitoring question for this indicator is:

"Has the area of oyster beds in Great Bay decreased from the 1997 level?"

Measurable Goal

The goal is for each bed to at least maintain its 1997 area as reported in Langan (1997). However, the TAC decided that it was not worthwhile to track the size of the oyster bed in the Bellamy River because of its small size even though it was included in the management objective above.

Data Analysis and Statistical Methods

The most recent estimates of oyster bed areas are compared to the 1997 baseline values. A rigorous statistical test for differences between 1997 and subsequent oyster bed areas is not possible. Instead, the error bars for the area estimate are used to establish an approximate "confidence interval" of possible values for the estimate.

Results

The six main oyster beds in Great Bay were mapped in 1997 by Langan (1997). In 2001, New Hampshire Fish and Game (NHF&G) and the University of new Hampshire (UNH), with funding support from NHEP, completed a new set of maps for four oyster beds using a method that combined information from acoustic sonar, videography, and diver surveys (NHF&G, 2002). The remaining two oyster beds were mapped by UNH in 2003 using videography techniques (Grizzle, 2004). The following table contains the oyster bed areas as measured in 1997, 2001 and 2003.

Table 1: Area (in acres) of the major oyster beds in Great Bay

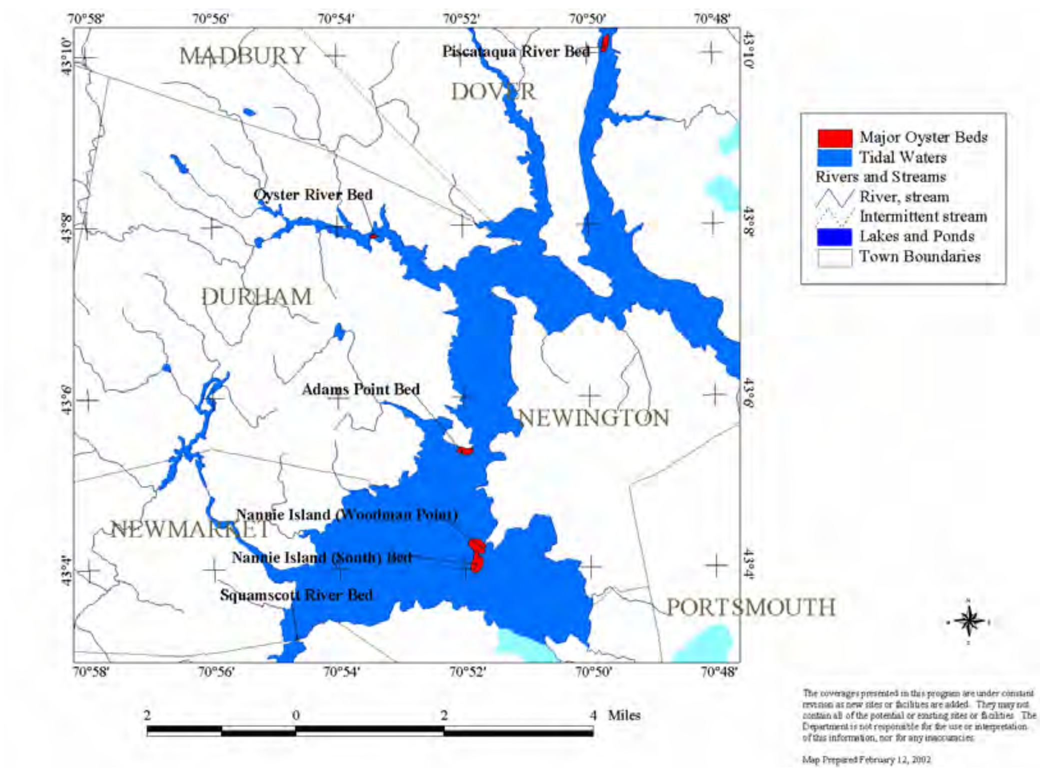
OYSTER BED	SIZE IN 1997[1] (ACRES)	SIZE IN 2001-3[2] (ACRES)	CHANGE (ACRES, %)
Nannie Island	37.3	24.7	12.6, -41%
Woodman Point	6.6	7.3	0.7, 10%
Piscataqua River	12.8	12.5	-0.3, -2%
Adams Point	4.0	13.1	9.1, 106%
Oyster River	1.8	1.7	-0.1, -6%
Squamscott River	1.7	1.9	0.2, 11%
TOTAL	**64 +/- 4**	**61 +/- 3**	**-3, -5%**

1. Areas from Langan (1997)
2. Areas from NHF&G (2002) and UNH (2004). For the Piscataqua and Squamscott beds, the area shown is for "high density" oysters (>50% coverage of bottom by oyster shell).

The total area of oyster beds in Great Bay has not changed significantly since 1997; therefore the NHEP goal is being met. In 1997, the six oyster beds covered 64 acres in total. In 2001 and 2003, the bed areas summed to 61 acres. The difference between these two estimates is less than the uncertainty in either of the values. To estimate the uncertainty, each bed area estimate was assumed to be accurate to +/-10%. The root mean square of the uncertainties in each bed area resulted in errors of +/- 4 acres and +/- 3 acres for the 1997 and 2001/2003 totals, respectively. For individual beds, the size of the Nannie Island and Adams Point beds decreased and increased, respectively. These discrepancies may be the result of changes in the mapping methods or how these beds were defined. In the future, the oyster beds will be mapped using the same methods as were employed in 2001and 2003 for comparability.

The general locations of the six oyster beds that are being tracked are shown in Figure 1. Maps of the individual beds, showing the outlines from 1997 compared to the 2001 and 2003 boundaries are provided in Figure 2 through Figure 6.

Figure 1: Major oyster beds in Great Bay



Source: NHEP Monitoring Plan (NHEP, 2004)

Figure 2: Boundaries of the Adams Point Oyster Bed, Great Bay, New Hampshire

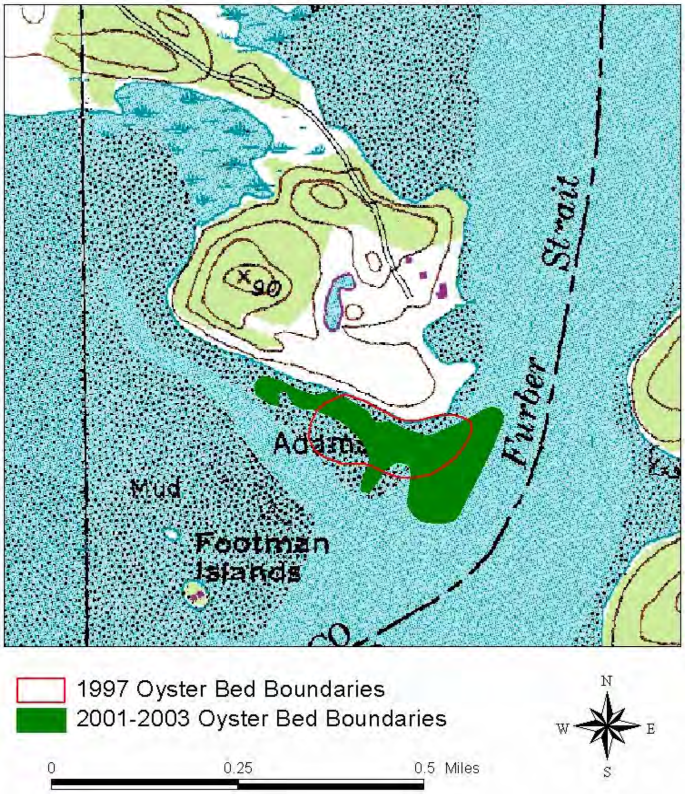


Figure 3: Boundaries of the Nannie Island and Woodman Point Oyster Beds, Great Bay, NH

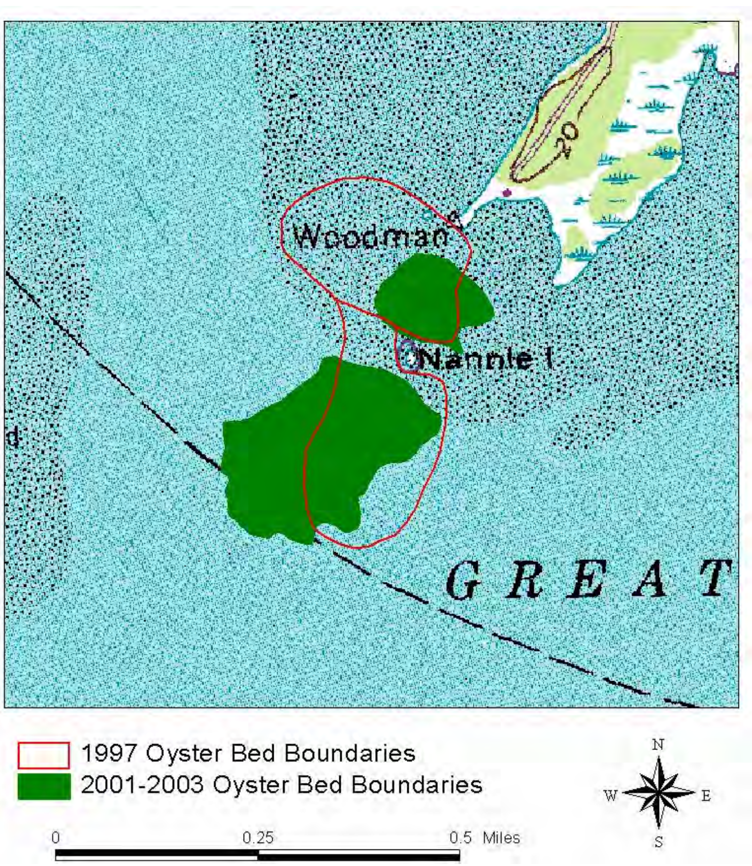


Figure 4: Boundary of the Squamscott River Oyster Bed, Great Bay, New Hampshire

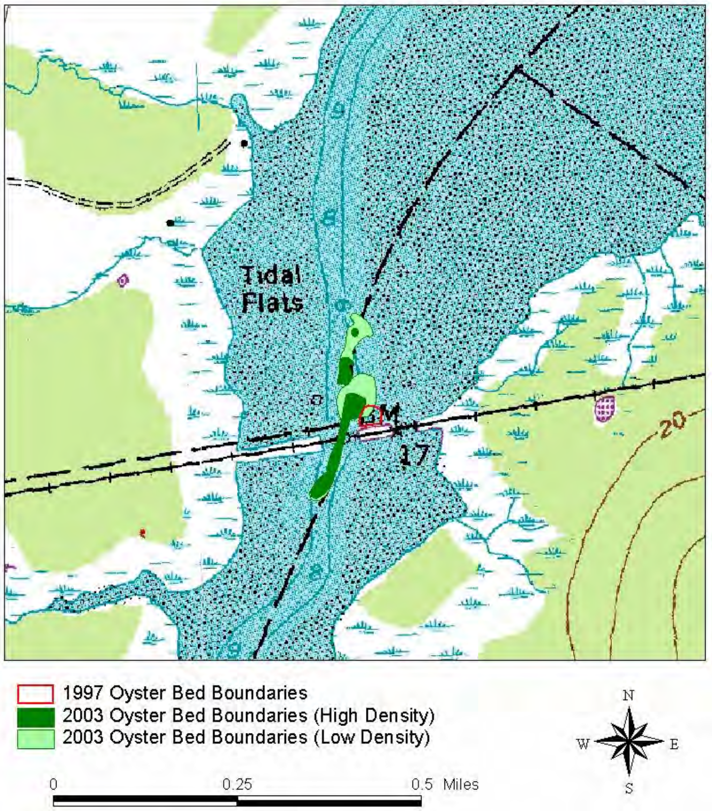


Figure 5: Boundaries of the Oyster River Oyster Bed, Great Bay, New Hampshire

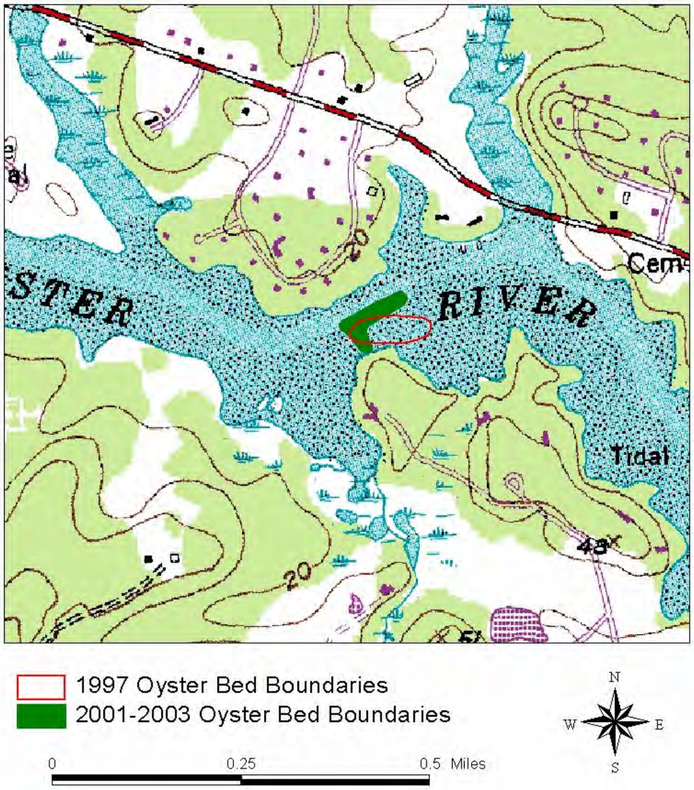
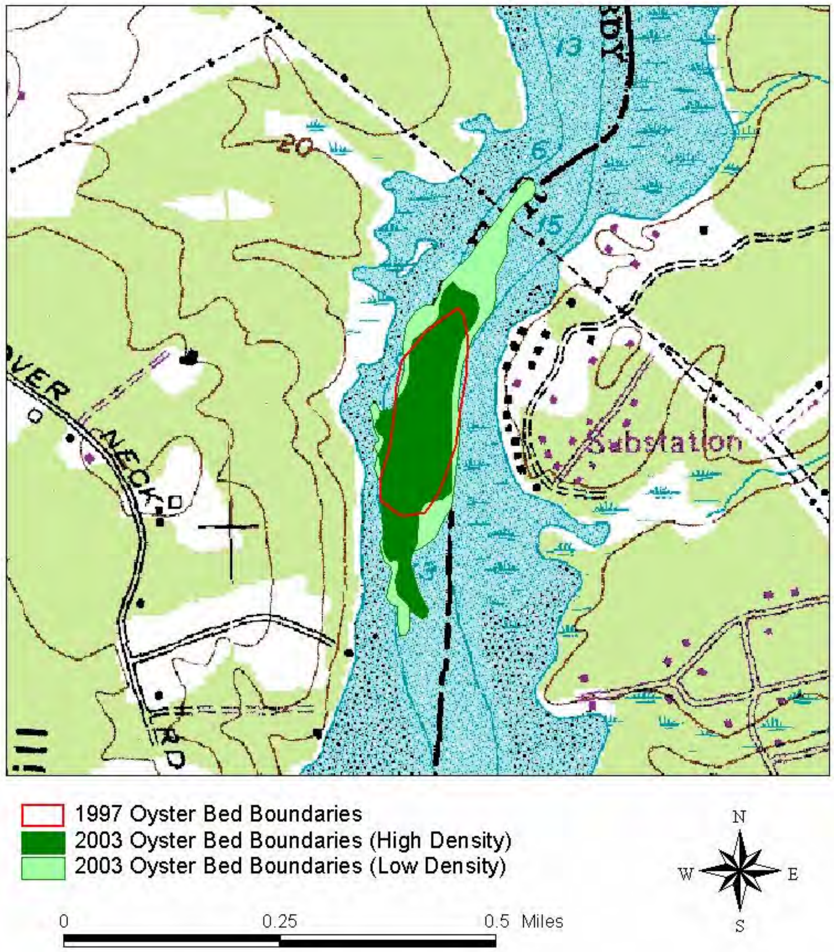


Figure 6: Boundaries of the Piscataqua River Oyster Beds, Great Bay, New Hampshire



SHL2 - DENSITY OF HARVESTABLE OYSTERS AT GREAT BAY BEDS

Monitoring Objective

The objective of this indicator is to estimate the average density of harvestable oysters at the six major oyster beds in Great Bay. This indicator is directly relevant to management objective "SHL1-4a: No net decrease in oysters (>80 mm shell height) per square meter from 1997 amounts at Nannie's Island, Woodman Point, Piscataqua River, Adams Point, and Oyster River." The Monitoring question for this indicator is:

"Has the density of harvestable-sized oysters in Great Bay beds decreased from 1997 levels?

Measurable Goal

The goal is for each bed to maintain its 1997 density (for oysters >80mm shell height). The oyster density in the Squamscott River bed was not measured in 1997; therefore, the 1998 density is the goal for this bed.

Data Analysis and Statistical Methods

For each bed, the arithmetic mean and standard deviation of the number of oysters >80mm shell height per quadrat are calculated. A one-sample, two-sided t-test with an alpha level of 0.05 is used to determine whether the densities are significantly different from the goals (1997 levels).

Results

Oysters have suffered a significant decline in recent years. Table 2 illustrates that densities are well below the NHEP goal of 1997 levels (statistically significant difference). The cause for this decline largely has been attributed to the protozoan pathogens MSX and Dermo. On average, the harvestable oyster densities in 2004 are 26% of the management goal (1997 levels). This average value is biased high because the density at the Oyster River bed is much closer to its goal (86%) than the other beds are (0-19%). The mean densities of harvestable oysters from 1993 to 2004 are presented in Figure 7.

Table 2: Average density (in # per m²) of harvestable size oysters at Great Bay beds

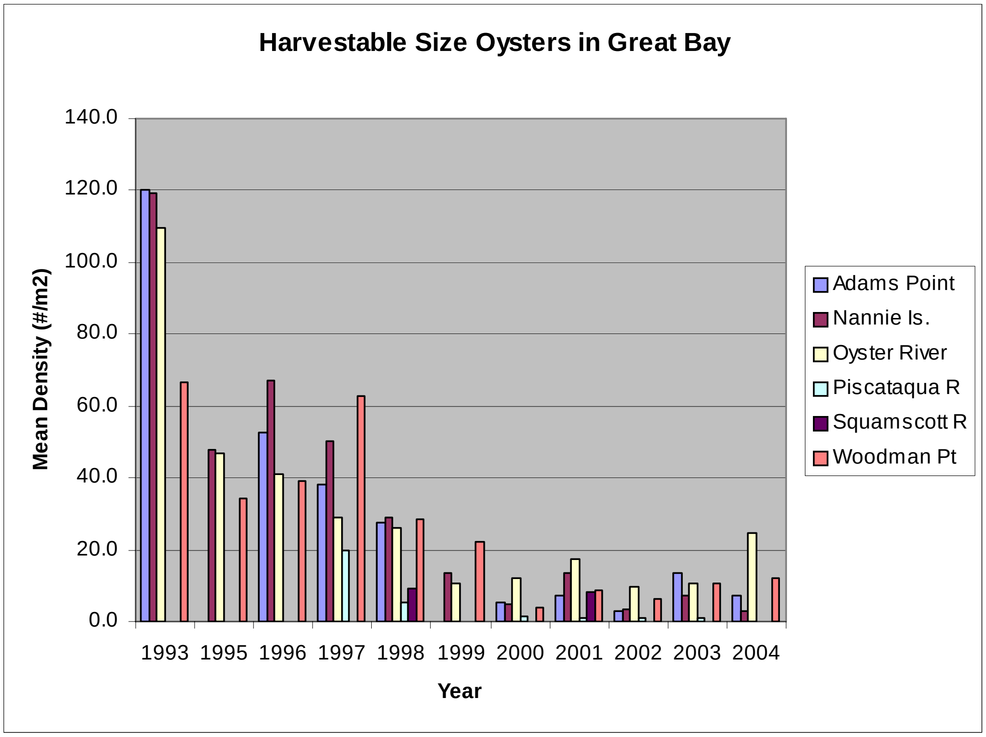
YEAR	ADAMS POINT	NANNIE ISLAND	OYSTER RIVER	PISCATA-QUA RIVER	SQUAM-SCOTT RIVER	WOODMAN POINT
1993	120.0	119.3	109.5			66.4*
1995		48.0	46.7			34.3
1996	52.7	67.0	40.8			39.0
1997	38.0	50.0	29.0	20.0		63.0
1998	27.5	28.7	26.0	5.1	9.3	28.7
1999		13.6	10.4	0.0		22.4
2000	5.3	4.8	12.0	1.3		4.0
2001	7.0	13.3	17.6	1.0	8.0	8.6
2002	2.8	3.2	9.6	0.8		6.4
2003	13.6	7.2	10.4	0.8		10.4
2004	7.2	2.7	24.8	0.0		12.0

Source: NHF&G (except 1997 data from Langan (1997)

1. Dark shaded cells are the NHEP Management Goals for harvestable oyster density from Langan (1997). The density at the Squamscott River bed was not measured in 1997 so the 1998 value from NHF&G is the goal for this bed.
2. Light shaded cells are statistically significant ($p<0.05$) decreases below management goals using a one sample, two-sided t-test.

* Average value from NHF&G summary reports. Raw data for individual quadrats not available for statistical significance analysis.

Figure 7: Average density of harvestable size oysters in Great Bay beds



SHL3 - DENSITY OF HARVESTABLE CLAMS AT HAMPTON HARBOR FLATS

Monitoring Objective

The objective of this indicator is to estimate the mean density of clams of harvestable size (>50mm shell length) from the major clam flats in Hampton Harbor. This indicator is directly relevant to management objective "SHL1-4b: No net decrease in adult clams (>50 mm shell length) per square meter from the 1989-1999 10-year average at Common Island, Middle Ground, and Confluence flats." The monitoring question for this indicator is:

"Has the density of harvestable-size clams in Hampton Harbor decreased from the historical average?"

Measurable Goal

The goal is for each flat to at least maintain the 10-year average density for clams of harvestable size (>50mm shell length) that was recorded between 1990 and 1999.

Data Analysis and Statistical Methods

For each flat, the arithmetic mean of the number of clams >50mm per quadrat is calculated. Ultimately, a one-sample t-test with an alpha level of 0.05 will be used to determine whether the densities are significantly different from the goal. However, information on the variance in density between quadrats is not currently available, therefore only the mean densities are reported for this analysis. The mean density values are compared to the goal.

Results

Table 3 shows that densities in 2003 were well below the most recent 10 year average (1990-1999) and falling for all three flats. The 2003 densities were also lower than the longer-term baseline densities recorded between 1974 and 1989.

Table 3: Average density (in # per m^2) of harvestable size clams in Hampton Harbor

FLAT	CURRENT STATUS (2003)	10 YEAR AVERAGE (1990-1999)	LONGER TERM BASELINE (1974-1989)
Common Island	3.0	21.3	15.3
Hampton-Browns Confluence	4.0	11.0	9.8
Middle Ground	7.0	38.6	9.9

Source: Seabrook Station

Table 4 and Figure 8 illustrate the trends in harvestable clam populations over the last 30 years. The densities have followed a cyclical pattern with a period of approximately 12 years. For instance, at Common Island, peak densities between 35.5 and 59.9 clams per square meter were observed in 1972, 1983, and 1997. Between these peaks, the harvestable clam density fell to 1-2 clams per square meter. All the flats were closed to harvesting due to bacterial pollution in 1989. The Common Island, Confluence, and Middle Ground flats were reopened in 1994, 1995, and 1998, respectively. The high clam densities in the 1990s occurred during this period. However, densities have decreased since their peak in 1997 even though the harvest from the flats has been relatively low since 1998.

The NHEP management goal for harvestable clam density is the 10-year average for the period between 1990 and 1999. During this period, the clam densities grew to unprecedented levels, due in part to the clam flats being closed for harvest. To capture the effects of the growth and decline cycles, a more suitable period for comparison is the longer-term baseline period of 1974 and 1989. The average values for 1974-1989 are not very different from the 1990-1999 period for the Common Island and Confluence flats. However, there is a sizeable difference for the Middle Ground flat.

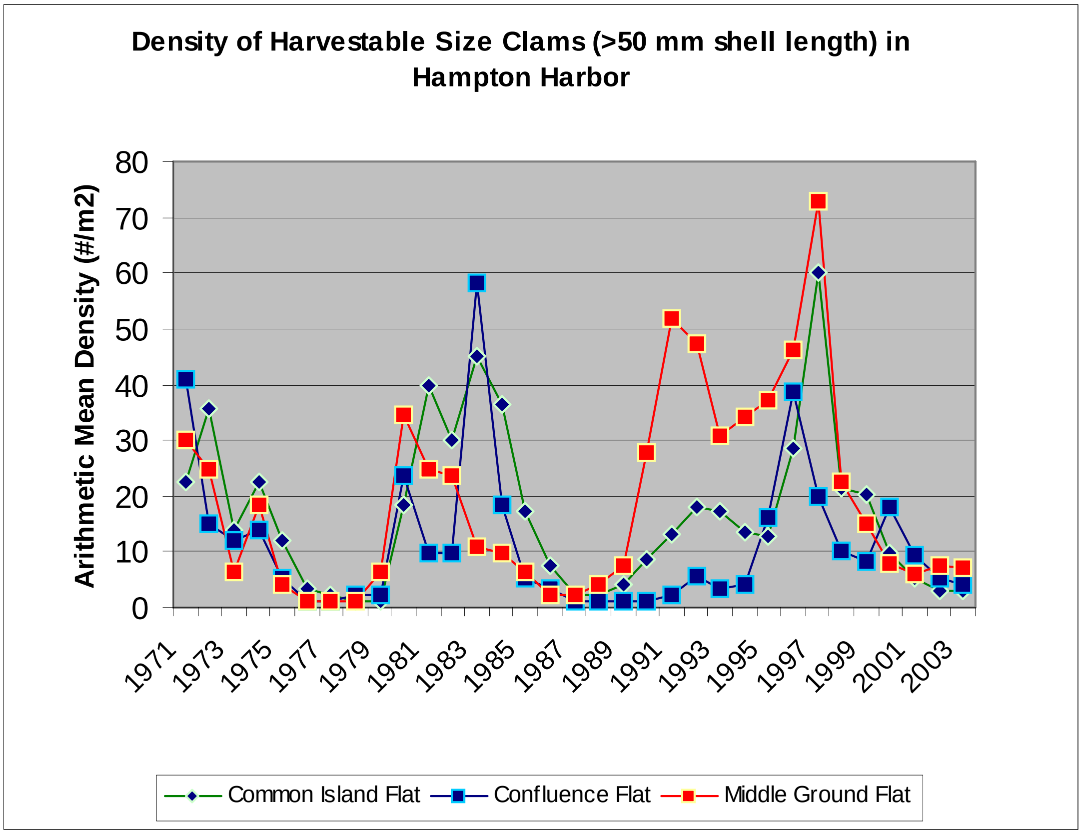
On average, the current harvestable clam densities in Hampton Harbor are 23% of the NHEP management goal and 44% of the long-term average densities from 1974 to 1989. The data presented in this report were collected before the 2004-2005 dredging operation in Hampton Harbor. Therefore, any effects of the dredging on the clam populations would not be evident from these data.

Table 4: Average density (in # per m^2) of harvestable size clams in Hampton Harbor

YEAR	COMMON ISLAND FLAT	CONFLUENCE FLAT	MIDDLE GROUND FLAT
1971	22.6	40.9	30.1
1972	35.5	15.1	24.8
1973	14.0	11.8	6.5
1974	22.6	14.0	18.3
1975	11.8	5.4	4.3
1976	3.2	1.1	1.1
1977	2.2	1.1	1.1
1978	1.1	2.2	1.1
1979	1.1	2.2	6.5
1980	18.3	23.7	34.4
1981	39.8	9.7	24.8
1982	30.1	9.7	23.7
1983	45.2	58.1	10.8
1984	36.6	18.3	9.7
1985	17.2	5.4	6.5
1986	7.5	3.2	2.2
1987	2.2	1.1	2.2
1988	2.2	1.1	4.3
1989	4.3	1.1	7.5
1990	8.6	1.1	27.9
1991	13.1	2.4	51.9
1992	18.1	5.8	47.2
1993	17.4	3.2	30.9
1994	13.7	4.2	34.1
1995	12.6	16.0	37.1
1996	28.5	38.8	46.3
1997	59.9	19.9	72.9
1998	21.3	10.0	22.5
1999	20.1	8.4	14.8
2000	9.8	18.1	7.7
2001	5.2	9.6	6.0
2002	3.0	5.3	7.5
2003	3.0	4.0	7.0

Source: Seabrook Station Environmental Monitoring Program
Shaded cells are less than the management goal for that flat. No tests of statistical significance could be performed.

Figure 8: Average density of harvestable size clams in Hampton Harbor



SHL4 - AREA OF CLAM FLATS IN HAMPTON HARBOR

Monitoring Objective

The objective of this supporting variable is to track the size of the three major clam flats in Hampton Harbor. This information will be combined with data on clam densities to estimate the standing stock of harvestable clams (indicator SHL6). The monitoring question for this indicator is:

"Has the area of clam flats in Hampton Harbor changed over time?"

Measurable Goal

This is a supporting variable so no measurable goal has been established. These data are collected to provide additional information to help interpret the results of other indicators.

Data Analysis and Statistical Methods

The area of each flat is reported along with the error in the estimate (if available). No statistical tests are applied.

Results

Table 5 and Figure 9 show the acreages of the three major clam flats mapped during 7 surveys. The latest available data on flat areas are from 2002. These data do not indicate any long-term trends in clam flat areas. However, in 2004-2005, the U.S. Army Corps of Engineers completed a large dredging operation in Hampton Harbor. The operation filled in a channel between the Middle Ground flat and Seabrook, reinforced the edge where the Blackwater River passes by the Middle Ground flat and dredged a channel through the northern edge of the Middle Ground flat. The Corps collected aerial images of the harbor monthly during the operation. Figures 10 to 11 illustrate how the clam flat boundaries changed as a result of the dredging operation.

Table 5: Area (in acres) of major clam flats in Hampton Harbor

YEAR	COMMON ISLAND FLAT	CONFLUENCE FLAT	MIDDLE GROUND	TOTAL
1977	54.9	27.2	49.7	131.8
1979	54.8	26.7	53.5	135.0
1981	54	24.7	50.8	129.5
1983	52.7	26.4	49.9	129.0
1984	50	21.7	47.9	119.6
1995	45.7	26.4	47.3	119.4
2002	36.9	23.4	57.8	118.1

Source: Seabrook Station Environmental Monitoring Program

Figure 9: Area of clam flats in Hampton Harbor

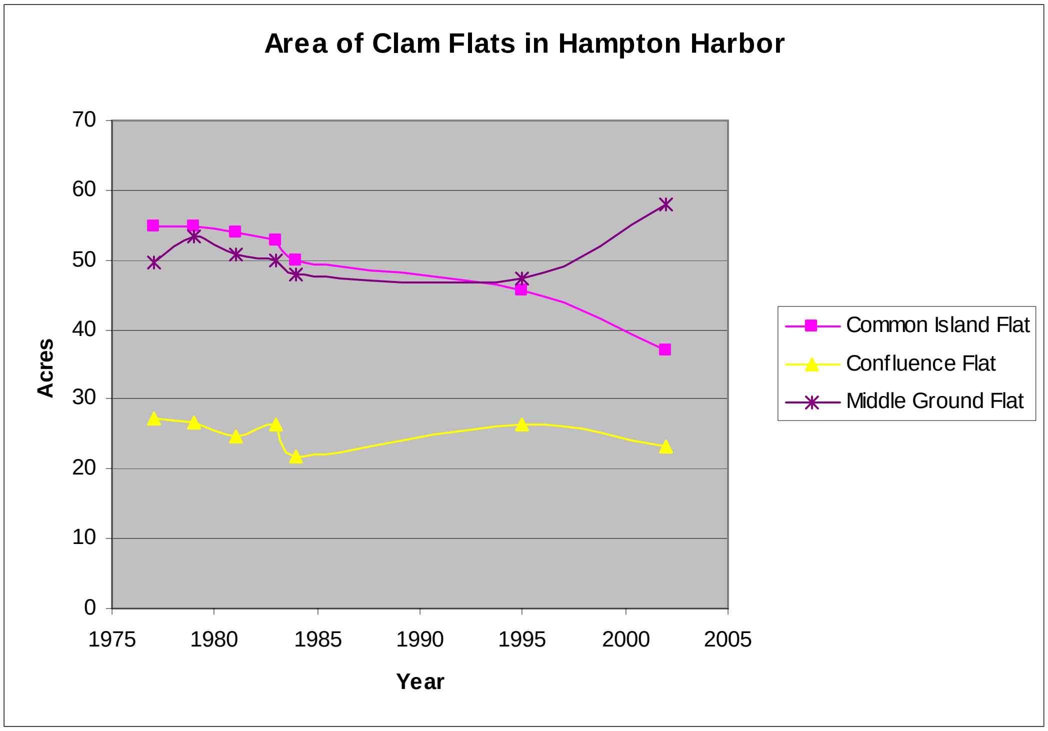


Figure 10: Major clam flats in Hampton Harbor before the dredging operation (10/3/04)

Source: U.S. Army Corps of Engineers

Figure 11: Major clam flats in Hampton Harbor after the dredging operation (4/5/2005)

Source: U.S. Army Corps of Engineers

SHL5 - STANDING STOCK OF HARVESTABLE OYSTERS IN GREAT BAY

Monitoring Objective

The objective of this indicator is to estimate the total number of harvestable oysters in Great Bay (i.e., oysters of harvestable size in beds that are open for harvesting). This indicator will answer the following monitoring question:

"Has the number of harvestable clams and oysters tripled from 1999 levels?"

This question will, in turn, report on progress towards a component of Shellfish Goal #1 which calls for the quantity of harvestable clams and oysters in New Hampshire's estuaries to be tripled.

Measurable Goal

In the NHEP Management Plan, Shellfish Goal #1 states that the quantity of harvestable clams and oysters in New Hampshire's estuaries should be tripled. The standing stock of harvestable oysters in 1999 was 15,883 bushels. Tripling 15,883 bushels is approximately 50,000 bushels. Therefore, the goal for this indicator is 50,000 bushels.

Data Analysis and Statistical Methods

The standing stock of harvestable oysters in each bed is estimated by multiplying the average density of oysters >80mm shell height by the most recent estimate of the bed size. Results are reported in bushels (for Great Bay, approximately 200 oysters equal 1 bushel). If data on density or area are missing for a bed for a particular year, the standing stock is estimated from the closest other available data for that bed. The standing stock estimates are summed for beds in areas open for harvesting. Rigorous statistical tests for differences are not possible.

Results

Data from 1993 to 2004 illustrate that the oyster fishery in Great Bay has suffered a serious decline. The 2004 standing stock is approximately 11% of the management goal of 50,000 bushels of harvestable oysters. The trends over time for oyster standing stock are shown in Table 6 and Figure 11.

Using a cost estimate of $0.45/oyster, the wholesale value of the fishery has dropped from over $11m in 1993 to $0.6m in 2004. (Note: This cost estimate is hypothetical because there is no commercial oyster harvesting in New Hampshire; moreover, the price varies depending on the season and other factors.)

The major cause of this decline is thought to be the protozoan pathogens MSX and Dermo which have caused similar declines in oyster fisheries in the Chesapeake and other mid-Atlantic estuaries.

Most of the current standing stock exists in beds that are open for harvesting.

Table 6: Harvestable oyster standing stock (in bushels) in Great Bay

YEAR	ADAMS POINT	NANNIE ISLAND	OYSTER RIVER	PISCATA-QUA RIVER	SQUAM-SCOTT RIVER	WOOD-MAN POINT	TOTAL - OPEN BEDS	TOTAL – ALL BEDS
1993	10,577	98,081	4,341	5,641	350	9,657	118,314	128,646
1995	7,609	39,451	1,851	5,641	350	4,986	52,047	59,889
1996	4,642	55,068	1,618	5,641	350	5,672	65,382	72,990
1997	3,349	41,095	1,150	5,641	350	9,162	53,607	60,748
1998	2,424	23,622	1,031	1,451	350	4,169	30,215	33,046
1999	1,447	11,178	412	0	325	3,258	15,883	16,620
2000	1,540	2,612	450	376	325	643	4,795	5,946
2001	2,021	7,257	659	282	300	1,379	10,656	11,897
2002	808	1,742	360	226	300	1,029	3,579	4,464
2003	3,926	3,919	390	220	335	1,673	9,517	10,462
2004	2,078	1,451	929	0	335	1,930	5,460	6,724

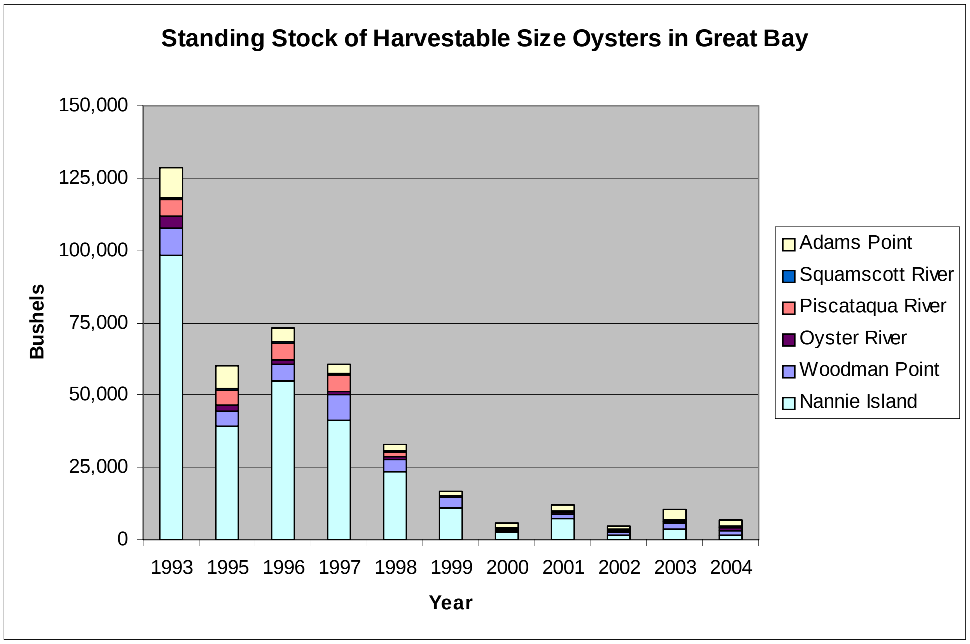
Sources: Langan (1997) for 1997 values and NHF&G for all other years.

Most of the values on this table are approximate because the oyster density and oyster bed boundary were not measured in the same year. In 1997, the density and boundary were mapped by Langan (1997) for all the beds except for the Squamscott River bed. In 2001, the density and boundary were mapped for the Adams Point, Nannie Island, Oyster River, and Woodman Point beds. In 2003, only the boundaries were mapped for the Piscataqua River and Squamscott River beds. Boundaries from 1997 were used up until the year that the beds were remapped (2003 for the Squamscott and Piscataqua beds and 2001 for all others). This simplification requires the assumption that the bed sizes have not changed over 4-6 years, which may not be justified. Area estimates from 2001 (and 2003 for Squamscott and Piscataqua beds) were used to estimate the standing stock in 2001 through 2004. The average harvestable oyster density for Woodman Point in 1993 was taken from NHF&G reports because raw data were not available to calculate this value independently.

Shaded cells indicate that an assumption regarding the density of oysters was needed to calculate the standing stock because density measurements were not taken at that bed in that year. Either the closest standing stock calculation from another year or an average of two bracketing standing stocks was used.

Open beds include Adams Point, Nannie Island, and Woodman Point. Closed beds are: Oyster River, Piscataqua River, and Squamscott River.

Figure 12: Harvestable size oyster standing stock in Great Bay



Note: The NHEP goal is 50,000 bushels of harvestable oysters.

SHL6 - STANDING STOCK OF HARVESTABLE CLAMS IN HAMPTON HARBOR

Monitoring Objective

The objective of this indicator is to estimate the total number of harvestable clams in Hampton Harbor (i.e., clams of harvestable size in Hampton Harbor flats that are open for harvesting). This indicator will answer the following monitoring question:

"Has the number of harvestable clams in Hampton Harbor changed over time?"

This question will, in turn, report on progress towards a component of Shellfish Goal #1 which calls for the quantity of harvestable clams and oysters in New Hampshire's estuaries to be tripled.

Measurable Goal

The 30 year average (1971-2000) of clam standing stock in Hampton Harbor is approximately 8,500 bushels. This period of time spans several cycles of the clam population and, therefore, is representative of long term average conditions. The NHEP uses 8,5000 bushels as a benchmark by which to judge whether clam standing stock in Hampton Harbor has changed over time.

Data Analysis and Statistical Methods

Seabrook Station calculates the the standing stock of harvestable clams in Hampton Harbor using the average density for each size clam on the flats (with 1 mm shell length increments for each size class), volume estimates for each size clam from Belding (1930), and the most recent area of each flat. The value of the clam fishery can be estimated by multiplying the standing crop value from Seabrook Station by the extremes of clam wholesale prices: summer ($250/bu) and winter ($50/bu). (Note: the value of the clam fishery is hypothetical because there is no commercial clam harvesting in New Hampshire).

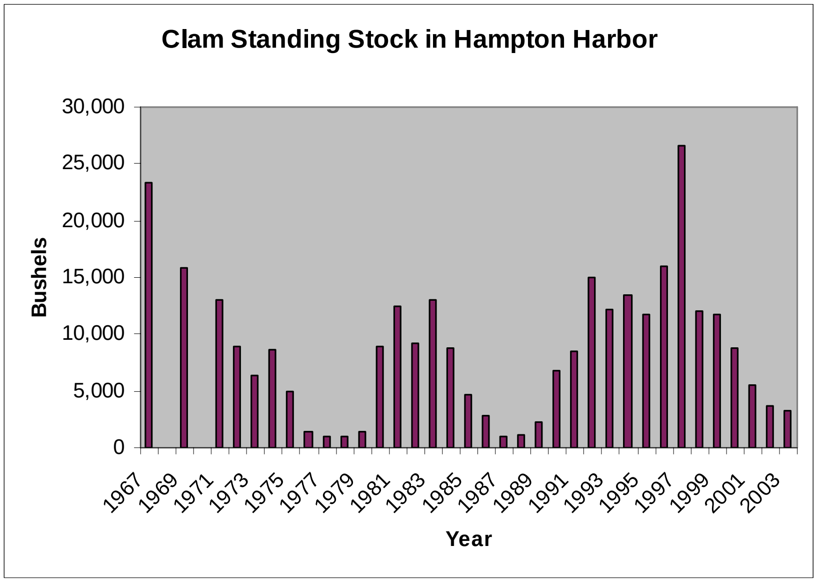
Results

Table 7 and Figure 12 show the history of harvestable clam standing stock over the past 36 years. The standing stock has undergone several 12-15 year cycles of growth and decline. Peak standing stocks of approximately 23,000, 13,000, and 27,000 bushels occurred in 1967, 1983, and 1997, respectively. Between the peaks, there have been crashes of the fishery in 1978 and 1987, with standing stock less than 1,000 bushels. Since 1997, the standing stock has been dropping once again but the 2003 levels have not yet reached the levels observed during the crashes in 1978 and 1987. The standing stock in 2003 was 3,276 bushels which is 39% of the NHEP management goal of 8,500 bushels. During the summer season when wholesale prices are approximately $250/bushel, the value of the fishery has been as high as $6.6m. The 2003 value was approximately $0.8m. (Note: This cost estimate is hypothetical because there is no commercial clam harvesting in NH.) The data presented in this report were collected before the 2004-2005 dredging operation in Hampton Harbor. Therefore, any effects of the dredging on the clam populations would not be evident from these data.

Table 7: Harvestable size clam standing stock (in bushels) in Hampton Harbor

YEAR	STANDING STOCK
1967	23,400
1969	15,840
1971	13,020
1972	8,920
1973	6,310
1974	8,690
1975	4,945
1976	1,350
1977*	1,060
1978	940
1979*	1,400
1980	8,890
1981*	12,400
1982	9,200
1983*	13,019
1984*	8,821
1985	4,615
1986	2,793
1987	976
1988	1,137
1989	2,295
1990	6,752
1991	8,462
1992	14,942
1993	12,161
1994	13,440
1995*	11,701
1996	16,001
1997	26,606
1998	11,992
1999	11,756
2000	8,765
2001	5,539
2002*	3,688
2003	3,276

Figure 13: Harvestable size clam standing stock in Hampton Harbor



Source: Seabrook Station Environmental Monitoring Program
*** Clam flat maps were made in this year so the standing stock estimate is accurate. All other values are estimates extrapolated using area estimates from the next closest year(s).**

SHL7. - ABUNDANCE OF SHELLFISH PREDATORS

Monitoring Objective

The objective of this supporting variable is to track the relative abundance of the dominant clam predator in New Hampshire tidal waters: green crabs (*Carcinus maenas*). This information will be used to help interpret changes in other indicators of shellfish density or standing stock, and will help to answer the following monitoring question:

"Are NH shellfish healthy, growing, and reproducing at sustainable levels?"

Measurable Goal

This is a supporting variable so no measurable goal has been established. These data are collected to provide additional information to help interpret the results of other indicators.

Data Analysis and Statistical Methods

The monthly catch-per-unit-effort (CPUE) of green crabs in Hampton Harbor is tracked over time. These data are generated by Seabrook Station using green crab traps set at four stations two times per month, April through January. The Mann-Kendall test is used to detect statistically signficant trends over time.

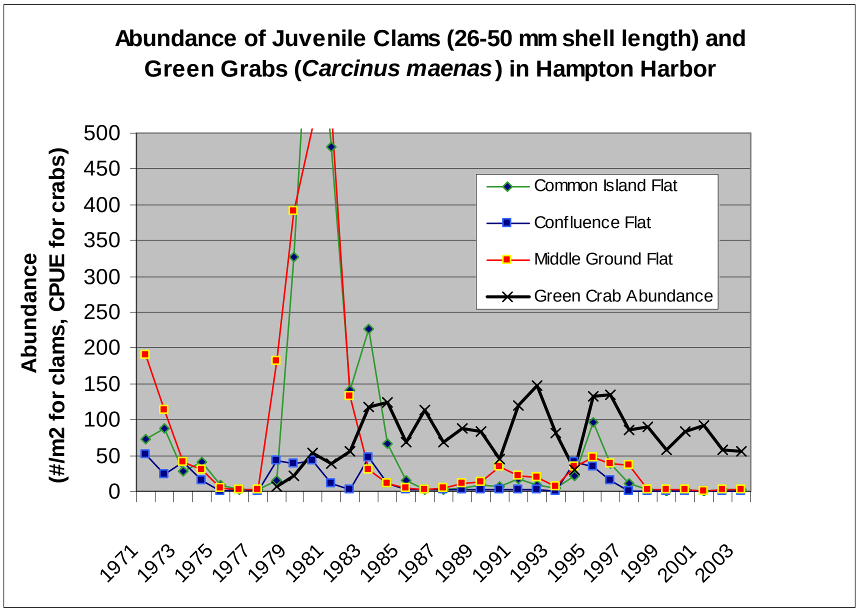
Results

The green crab is an invasive species which was introduced from Europe and currently exists along the Atlantic coast from Nova Scotia to Delaware. Time series data on green crab abundance in Hampton Harbor are shown in Table 8 and Figure 13. There is no statistically significant trend in the abundance values over time. Seabrook Station and others have observed that green crab abundance is somewhat correlated with yearly minimum water temperatures (FPL, 2003). Green crabs prey on juvenile clams. Figure 14 shows that juvenile clam populations are low during years with high crab abundance and rebound when the crab abundance falls below 50 CPUE.

Table 8: Green crab abundance in Hampton Harbor

YEAR	CATCH PER UNIT EFFORT
1978	7.2
1979	22.1
1980	53.1
1981	39.4
1982	56.1
1983	117.3
1984	123.9
1985	69.4
1986	113.5
1987	68.9
1988	88.2
1989	82.5
1990	44
1991	120.1
1992	146.5
1993	81.4
1994	30.5
1995	132.4
1996	135.4
1997	84.8
1998	88.9
1999	57.9
2000	83.1
2001	91.8
2002	58.6
2003	56.3
2004	50.2

Figure 14: Green crab and juvenile clam abundance in Hampton Harbor



Source: Seabrook Station Environmental Monitoring Program

SHL8 - CLAM AND OYSTER SPATFALL

Monitoring Objective

The objective of this supporting variable is to track the yearly spatfall of clams in Hampton Harbor and oysters in Great Bay. This information will be used to help interpret changes in other indicators of shellfish density or standing stock, and will help to answer the following monitoring question:

"Are NH shellfish healthy, growing, and reproducing at sustainable levels?"

Measurable Goal

This is a supporting variable so no measurable goal has been established. These data are collected to provide additional information to help interpret the results of other indicators.

Data Analysis and Statistical Methods

For oysters, spatfall is measured by the density of oysters less than or equal to 20 mm shell height during the fall season. For clams, the spat size is defined as 1-25 mm shell length. This range is relatively large and may include some clams from the yearling age class. The average spat density at each major oyster bed and clam flat are tracked over time. No statistical tests are applied.

Results

Oyster Spatfall

Table 9 and Figure 14 show that there was a large spat set at almost all of the Great Bay oyster beds in 2002. The last observed spat set before 2002 was in 1998 and 1999; however, the spat densities during these years were much lower than in 2002. The spat sets in 2003 and 2004 were minimal. However, the oysters from the spat set in 2002 have formed a large class of juvenile oysters (21-80 mm in length) that had not yet reached harvestable size in 2004 (Figure 16).

Table 9: Average oyster spat density (in # per m^2) in Great Bay

YEAR	ADAMS POINT	NANNIE ISLAND	OYSTER RIVER	PISCATAQUA RIVER	SQUAMSCOTT RIVER	WOODMAN POINT
1993	0.0	0.7	0.0			
1995		0.0	0.7			8.0
1996	0.0	1.0	0.0			1.0
1998	6.0	14.1	5.3	7.4	41.3	4.0
1999		11.2	31.2	32.8		65.6
2000	2.7	5.6	1.6	8.0		5.3
2001	0.0	0.7	2.4	0.0	20.0	1.1
2002	62.0	0.8	139.2	300.8		96.0
2003	4.0	3.2	9.6	4.8		1.6
2004	0.0	0.0	0.0	0.8		0.8

Source: NHF&G
Mean values are arithmetic averages. Spat is defined as oysters with 1-20 mm shell height.

Figure 15: Average oyster spat density in Great Bay

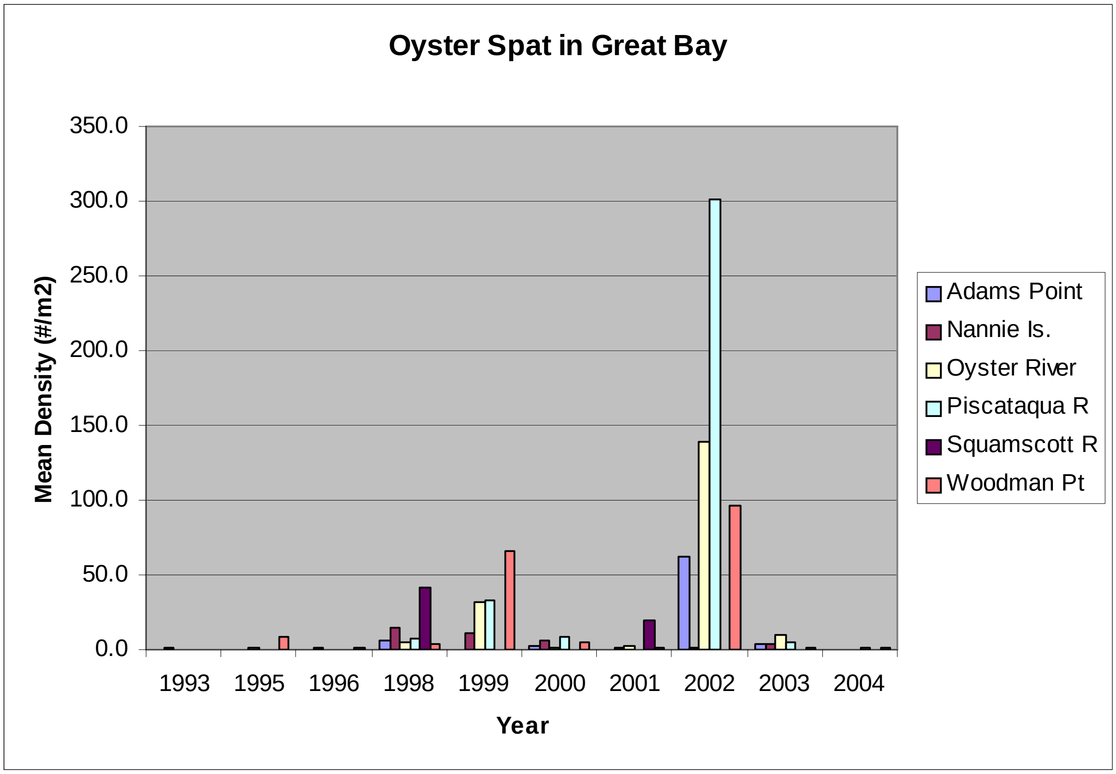
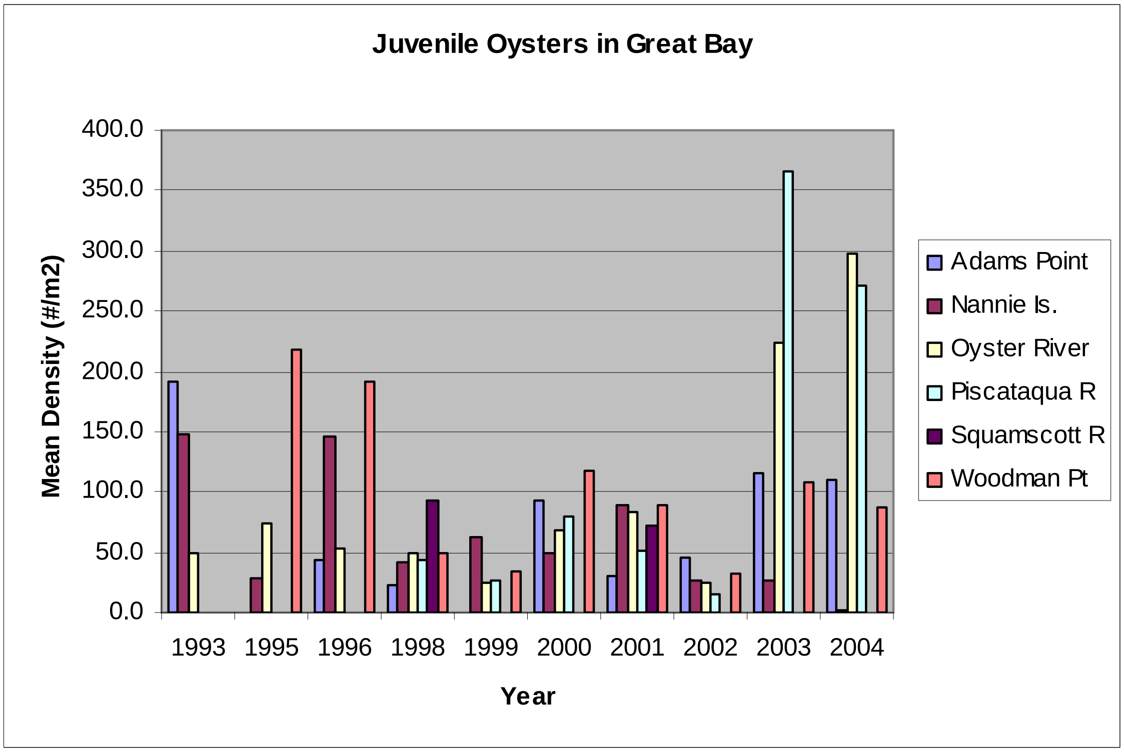


Figure 16: Average juvenile oyster density in Great Bay



Clam Spatfall

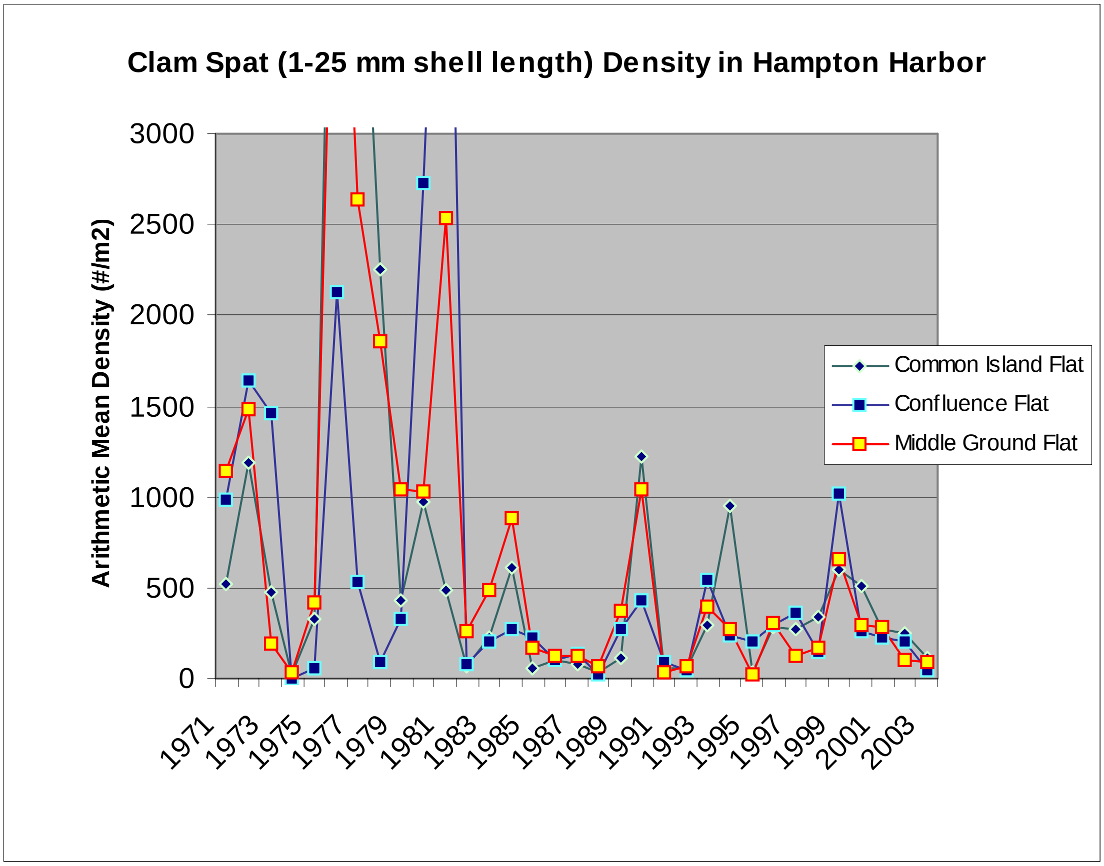
Table 10 and Figure 15 illustrate that spatfall has fluctuated on approximately four year intervals over the past 30 years. Very large spatfalls occurred in the late 1970s and early 1980s. The spatfall in 2003 was one of the lowest on record.

Table 10: Average clam spat density (in # per m^2) in Hampton Harbor

YEAR	COMMON ISLAND FLAT	CONFLUENCE FLAT	MIDDLE GROUND FLAT
1971	517	979	1,141
1972	1,184	1,636	1,485
1973	474	1,464	194
1974	22	0	32
1975	334	54	420
1976	6,243	2,131	5,113
1977	4,704	527	2,637
1978	2,250	86	1,851
1979	431	334	1,044
1980	969	2,723	1,033
1981	484	5,586	2,540
1982	65	75	258
1983	226	205	484
1984	614	269	883
1985	54	226	172
1986	97	97	129
1987	75	140	129
1988	32	22	65
1989	118	269	377
1990	1,227	431	1,044
1991	62	86	38
1992	59	41	70
1993	298	542	392
1994	956	235	275
1995	36	200	25
1996	279	289	304
1997	267	359	123
1998	336	153	171
1999	605	1,016	654
2000	514	261	291
2001	271	225	282
2002	253	201	99
2003	117	41	85

Source: Seabrook Station Environmental Monitoring Program
Clam spat is defined as clams with 1-25 mm shell length.
Mean values are arithmetic averages.

Figure 17: Average clam spat density in Hampton Harbor



SHL9 - RECREATIONAL HARVEST OF OYSTERS

Monitoring Objective

The objective of this supporting variable is to estimate how many oysters are harvested by recreational harvesters each year (Great Bay is not a commercial oyster fishery). This information is needed to answer the following monitoring question:

"Are NH shellfish being harvested at sustainable levels?"

Measurable Goal

This is a supporting variable so no measurable goal has been established. These data are collected to provide additional information to help interpret the results of other indicators.

Data Analysis and Statistical Methods

The total number of oysters licenses sold yearly are compiled from the NH Fish and Game Department. Periodically, the actual number of oysters harvested from the entire Great Bay Estuary is estimated. The license sales and harvest are tracked over time and compared to the annual estimate of standing stock. No statistical tests are applied to these data.

Results

In Table 11, the historical record of recreational harvest license sales has been combined with the available estimates of oyster harvest. For the years when estimates of oyster harvest were made, the results have been compared to oyster standing stock estimates from indicator SHL-5.

The data indicate a progressive decline in license sales and a proportional decline in total harvest. License sales fell 88% between 1981 and 2004 (Figure 18). In 1996, the total harvest amounted to approximately 4% of the standing stock. Based on this comparison, the current levels of harvest appear to be sustainable.

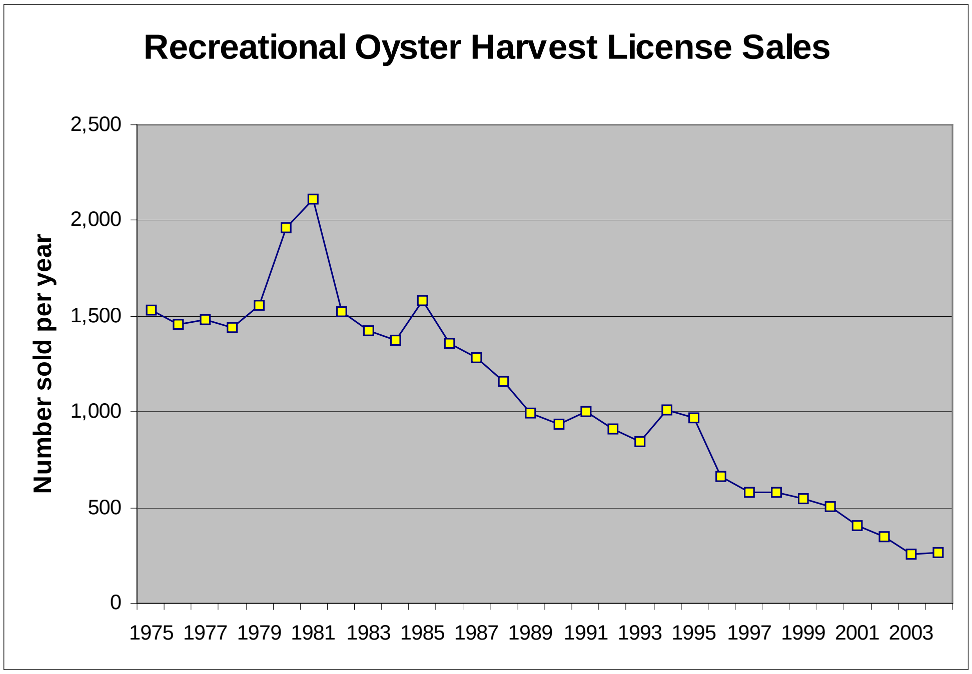
The fee for an oyster harvesting license for a New Hampshire resident is $30 per year. In 2004, the total number of license sold was 262, generating $7,860 in revenue. If license sales were to return to peak values from the 1980s, then revenues from license sales would be approximately $60,000.

Table 11: Recreational oyster harvest - license sales and harvest estimates

YEAR	LICENSE SALES*	HARVEST (BUSHELS)	STANDING STOCK (BU)	HARVEST AS A PERCENT OF STANDING STOCK
1975	1532			
1976	1460			
1977	1479			
1978	1440			
1979	1553			
1980	1961			
1981	2109			
1982	1522			
1983	1426			
1984	1373			
1985	1582			
1986	1358			
1987	1285			
1988	1157			
1989	992	>4,000	128,646 (1)	3.1%
1990	932			
1991	1001			
1992	907			
1993	847			
1994	1009			
1995	971			
1996	661	2,727	72,990 (2)	3.7%
1997	582			
1998	579			
1999	545			
2000	506			
2001	406			
2002	344			
2003	253			
2004	262			

Source: Oyster harvest license sales provided by NHF&G
(1) Using earliest standing stock estimate (1993) from indicator SHL-5 to represent the "late 1980s". Harvest estimate is from Manalo et al. (1991).
(2) Using standing stock estimate for 1996 from indicator SHL-5. Harvest estimate is from NHF&G (1997).

Figure 18: Recreational oyster harvest license sales



SHL10 - RECREATIONAL HARVEST OF CLAMS

Monitoring Objective

The objective of this supporting variable is to estimate how many clams are harvested from Hampton Harbor flats by recreational harvesters each year (Hampton Harbor is not a commercial clam fishery). This information is needed to answer the following monitoring question:

"Are NH shellfish being harvested at sustainable levels?"

Measurable Goal

This is a supporting variable so no measurable goal has been established. These data are collected to provide additional information to help interpret the results of other indicators.

Data Analysis and Statistical Methods

The total number of clams harvested yearly are estimated for the Hampton Harbor flats based on the number of harvesters observed and estimated by the Seabrook Station monitoring program during the clamming season. Assuming that each harvester takes his limit (10 liquid quarts per person per day), the total harvest for the day can be estimated. The daily harvests are totaled to estimate the yearly harvest. The annual harvest and the number of clam license sold are tracked over time and compared to annual estimates of standing stock. No statistical tests are applied to these data.

Results

In Table 12, data on clam harvests by Seabrook Station and clam license sales by NHF&G have been compiled for the past 29 years. The data show that harvests during the 1980s were a high percentage of the standing stock before the fishery crashed in the late 1980s. Harvests were zero during the early 1990s because the flats were closed. Following the re-opening of the flats, harvests have increased but have remained low, presumably because the flats are often closed due to high bacteria concentrations. Both the harvest and standing stock values are estimates, and the error in these estimates is well illustrated by the data for 1987 which shows a harvest value greater than the standing stock value.

License sales provide a slightly longer record back to 1975 (Figure 20). These data provide an indication that harvest pressure was high preceding the other documented crash of the fishery in the late 1970s. License sales declined by 87% between 1981 and 2004.

The Seabrook Station harvest estimates ended after 2002 when new regulations prohibited clamming on Fridays, which was the day of the week when Seabrook Station had counted harvest pressure. For 23 years (1980-2002), the Seabrook Station harvest estimates overlapped with clam license sales. The two indicators of harvest pressure are well correlated ($r2=0.93$) (Figure 19). Therefore, the clam license sales can be used as the continuing measure of harvest pressure in Hampton Harbor.

In 2004, the New Hampshire Fish and Game Department sold 1,198 clam licenses for an annual fee of $30 per license. Therefore, the total revenue from license sales was $35,940 in 2004. If the license sales were to return to the peak values from the 1980s, then revenues from license sales would be approximately $250,000 per year.

Table 12: Recreational clam harvest from Hampton Harbor and clam license sales

YEAR	DIGGER TRIPS PER YEAR)			ESTI-MATED HARVEST (BUSHELS	LICENSE SALES*
	COMMON ISLAND	CONFLUENCE FLAT	MIDDLE GROUND		
1975					12,681
1976					7,128
1977					2,735
1978					1,773
1979					2,164
1980	246	371	1,098	1,715	4,837
1981	686	894	3,982	5,561	9,118
1982	1,198	686	4,029	5,913	8,648
1983	1,353	478	2,554	4,385	7,824
1984	920	1,040	1,757	3,716	7,056
1985	1,686	290	1,066	3,041	6,616
1986	2,006	218	1,159	3,384	5,283
1987	404	78	510	992	2,920
1988	122	73	368	563	1,881
1989	25	12	73	109	904
1990	0	0	0	0	286
1991	0	0	0	0	318
1992	0	0	0	0	287
1993	0	0	0	0	248
1994	470	0	0	470	2,940
1995	232	0	0	232	1,652
1996	11	143	0	153	1,183
1997	106	602	0	708	1,433
1998	471	133	55	659	2,355
1999	498	194	330	1,022	3,217
2000	348	13	33	394	3,144
2001	2,453	199	96	859	2,350
2002	370	833	0	376	1,900
2003	NA	NA	NA	NA	1,085
2004	NA	NA	NA	NA	1,198

Source: Digger trips and harvest provided by Seabrook Station. License sales provided by NHF&G.

Figure 19: Relationship between clam license sales and clam harvest in Hampton Harbor, 1980-2002

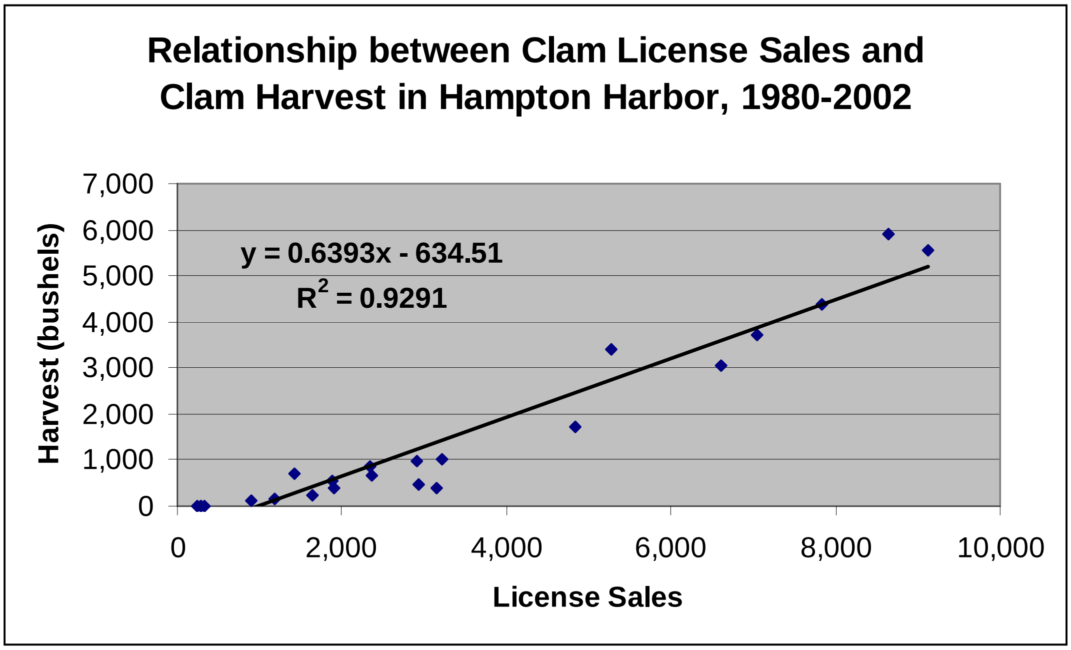
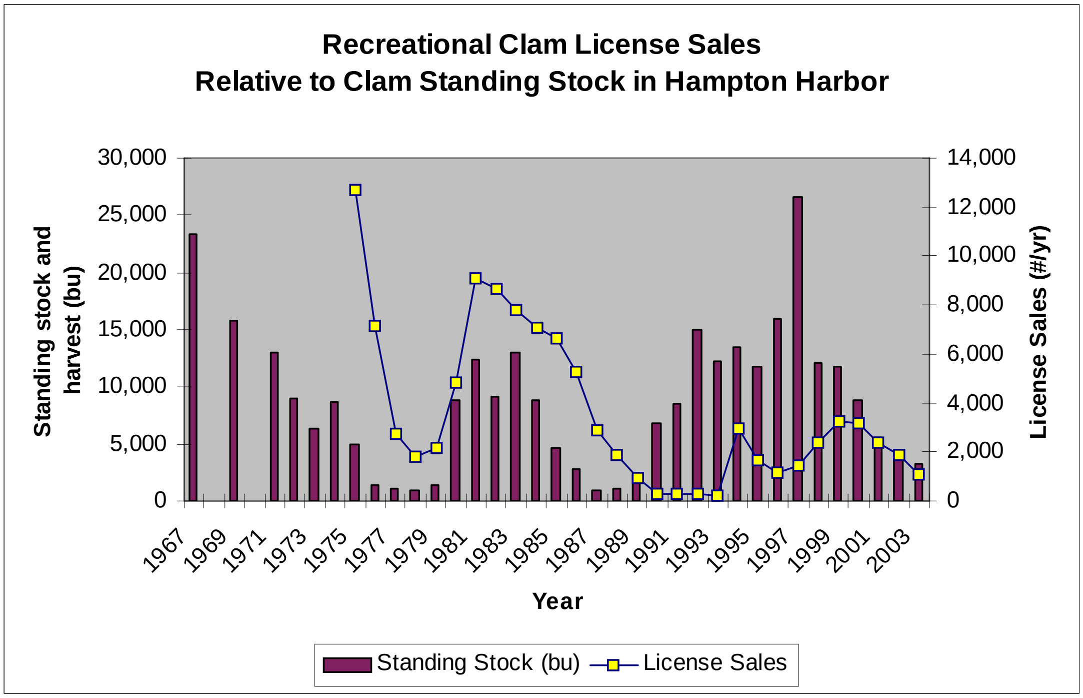


Figure 20: Clam license sales relative to clam standing stock in Hampton Harbor



SHL11 - PREVALENCE OF OYSTER DISEASE

Monitoring Objective

The objective of this supporting variable is to estimate the prevalence of the oyster diseases, MSX and Dermo. This information is needed to answer the following monitoring question:

"Has the incidence of shellfish diseases changed significantly over time?"

Measurable Goal

This is a supporting variable so no measurable goal has been established. These data are collected to provide additional information to help interpret the results of other indicators.

Data Analysis and Statistical Methods

For each oyster bed, the percent of oysters infected with MSX or Dermo are reported and tracked over time. The Mann Kendall Test is used to test for significant trends over time.

Results

MSX

The disease MSX was first detected in Delaware Bay in 1957 and since then has spread throughout the Atlantic coast. The protozoa that causes MSX (*Haplosporidium nelsoni*) is mainly controlled by salinity. The protozoa cannot survive in low salinity water (<10 ppt), has limited virulence at salinities between 10 and 20 ppt, and is fully infectious at salinities >20 ppt (Haskin and Ford, 1982). Therefore, droughts tend to increase the prevalence of MSX infections and allow for expansion of the protozoa's range.

Unspeciated haplosporidian plasmodia were observed in the Piscataqua River as early as 1979 by Maine Department of Marine Resources. The presence of MSX in Great Bay was first conclusively determined in 1983. However the first oyster mortality from the disease was observed in 1995 following a severe drought (Barber et al., 1997).

The NH Fish and Game Department has monitored the prevalence of MSX in oysters from the Great Bay every year since 1995 (NHF&G, 2005). No statistically significant change in MSX infection rates at Nannie Island has occurred since the disease was first detected (Table 13, Figure 21) Approximately 20% of the oysters in Great Bay are currently infected. The rate of systemic infection (5% on average in 2004) is also important because systemic infection is a portent of imminent death, whereas oysters with low grade infections will often survive for at least another year.

Table 13: Prevalence of MSX infection in Great Bay oysters

Date	Year	Location	Number Tested	Percent Infected	Percent with Systemic Infection	Notes
11/06/95	1995	Adams Point	20	40%	15%	(3)
05/27/96	1996	Adams Point	10	0%	0%	
11/17/97	1997	Adams Point	25	40%	20%	
12/09/98	1998	Adams Point	25	28%	8%	
11/04/00	2000	Adams Point	20	35%	25%	
11/04/01	2001	Adams Point	20	25%	20%	
10/14/02	2002	Adams Point	20	45%	0%	
10/14/02	2002	Adams Point	20	45%	0%	
11/19/04	2004	Adams Point	19	11%	5%	
11/06/95	1995	Nannie Island	20	15%	5%	(3)
05/27/96	1996	Nannie Island	40	8%	0%	(1)
11/17/97	1997	Nannie Island	25	52%	28%	
12/09/98	1998	Nannie Island	25	44%	8%	
10/21/99	1999	Nannie Island	20	35%	30%	
11/04/00	2000	Nannie Island	20	30%	25%	
10/10/01	2001	Nannie Island	24	21%	17%	
10/31/02	2002	Nannie Island	24	37%	17%	
10/31/02	2002	Nannie Island	24	37%	17%	
10/28/03	2003	Nannie Island	26	8%	0%	
11/18/04	2004	Nannie Island	17	29%	6%	
12/18/95	1995	Oyster River	20	50%	30%	(3)
11/17/97	1997	Oyster River	25	36%	8%	
11/15/00	2000	Oyster River	20	35%	10%	
11/04/01	2001	Oyster River	20	25%	20%	
10/14/02	2002	Oyster River	20	45%	5%	
10/14/02	2002	Oyster River	20	45%	5%	
10/27/04	2004	Oyster River	24	25%	4%	
10/27/95	1995	Piscataqua River	45	71%	33%	(2) (3)
11/17/97	1997	Piscataqua River	25	60%	20%	
12/09/98	1998	Piscataqua River	18	39%	17%	
11/04/00	2000	Piscataqua River	20	30%	15%	
09/08/97	1997	Squamscott River	25	44%	20%	
12/09/98	1998	Squamscott River	25	68%	28%	

Source: NHF&G except where noted
(1) Combination of 30 samples taken 4/12/96 and 10 samples taken 5/27/96
(2) Combination of 25 oysters tested on 9/5/95 and 20 oysters tested on 10/27/95. Samples taken at "summer bed".
(3) Source: Barber et al. (1997)

Figure 21: Prevalence of MSX infection in Great Bay oyster beds

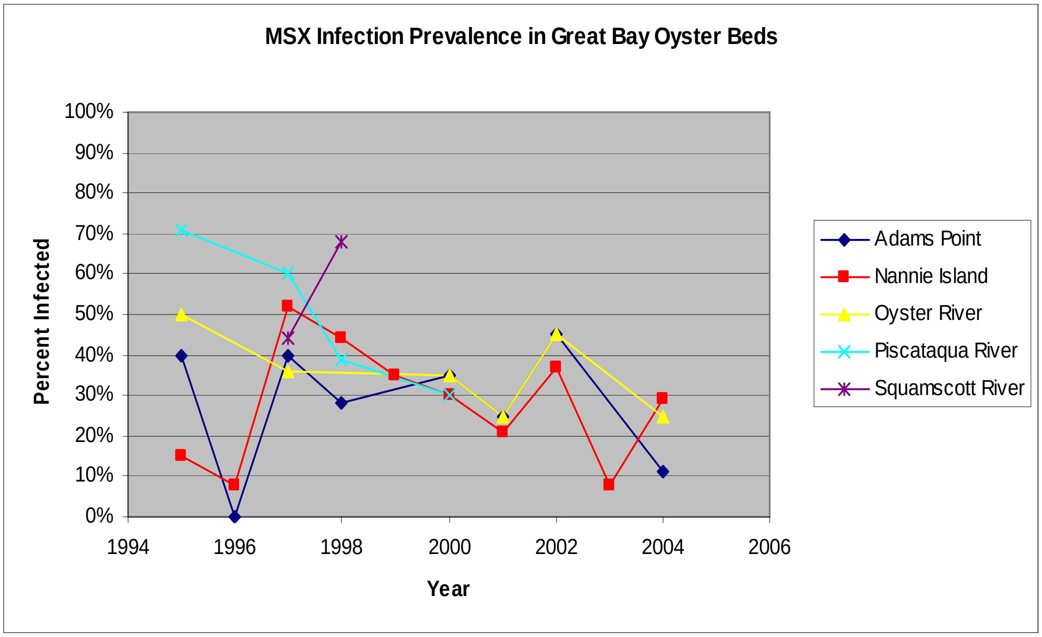
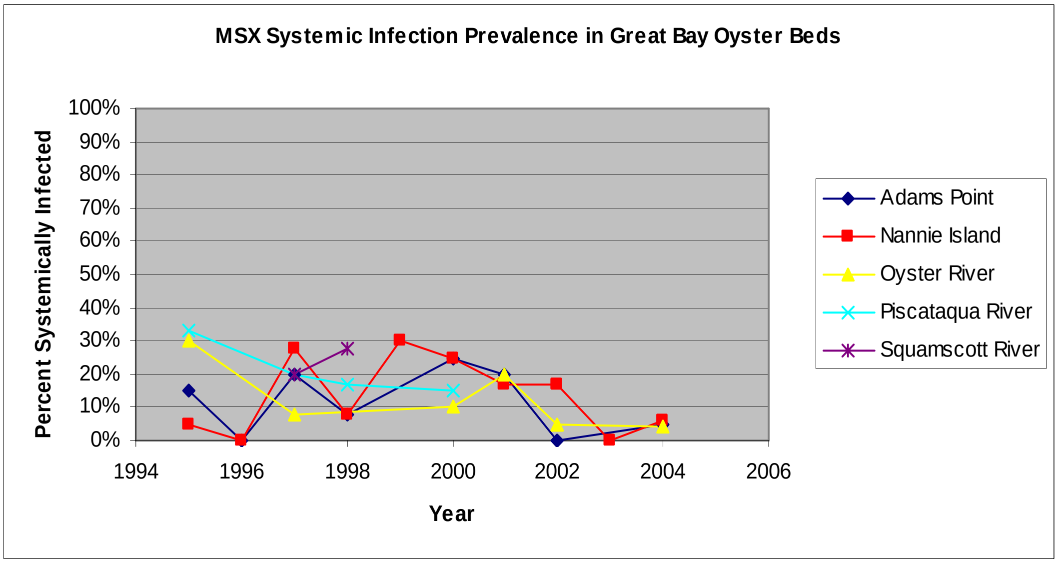


Figure 22: Prevalence of systemic MSX infection in Great Bay oyster beds



Dermo

The other major oyster disease present in Great Bay is Dermo which is caused by the protozoa *Perkinsus marinus*. The NH Fish and Game Department has monitored the prevalence of Dermo in oysters from the Great Bay every year since 1995 (NHF&G, 2005). The infection prevalence of Great Bay oysters by Dermo has been less severe than MSX until recently. In 1997, only 10% of oysters from any bed were infected with the disease. Between 1998 and 2001, Dermo was not found in New Hampshire waters except at the Salmon Falls River bed (not shown). In 2002, oysters from Adams Point, Nannie Island, and the Salmon Falls River were found to be infected with Dermo again. By 2004, the prevalence of Dermo infection was approximately 60% in the Nannie Island and Adams Point oyster beds (NHF&G, 2005). However, only 6-20% of the oysters at these beds were considered heavily infected with the disease. This level of the disease was last seen in 2001 and 2002 at the oyster bed in the Salmon Falls River.

Table 14: Prevalence of Dermo infection in Great Bay oysters

Date	Year	Location	Number Tested	Percent Infected	Percent Heavily Infected
11/17/97	1997	Adams Point	50	10%	0%
12/09/98	1998	Adams Point	25	0%	0%
11/04/00	2000	Adams Point	20	0%	0%
11/04/01	2001	Adams Point	20	0%	0%
10/14/02	2002	Adams Point	20	15%	0%
11/19/04	2004	Adams Point	20	65%	20%
12/16/96	1996	Nannie Island	25	4%	0%
11/17/97	1997	Nannie Island	50	2%	0%
12/09/98	1998	Nannie Island	25	0%	0%
10/21/99	1999	Nannie Island	20	0%	0%
11/04/00	2000	Nannie Island	20	0%	0%
10/10/01	2001	Nannie Island	25	0%	0%
10/31/02	2002	Nannie Island	24	8%	0%
10/28/03	2003	Nannie Island	25	20%	8%
11/18/04	2004	Nannie Island	17	59%	6%
11/17/97	1997	Oyster River	50	2%	0%
11/15/00	2000	Oyster River	20	0%	0%
11/04/01	2001	Oyster River	20	0%	0%
10/14/02	2002	Oyster River	20	0%	0%
10/27/04	2004	Oyster River	25	16%	0%
11/17/97	1997	Piscataqua River	50	10%	2%
12/09/98	1998	Piscataqua River	18	0%	0%
11/04/00	2000	Piscataqua River	20	0%	0%
09/08/97	1997	Squamscott River	25	4%	0%
12/09/98	1998	Squamscott River	25	0%	0%

Source: NHF&G
Infections are considered "heavy" if they are capable of posing a threat to Dermo-free oysters.

Figure 23: Prevalence of Dermo infection in Great Bay oysters

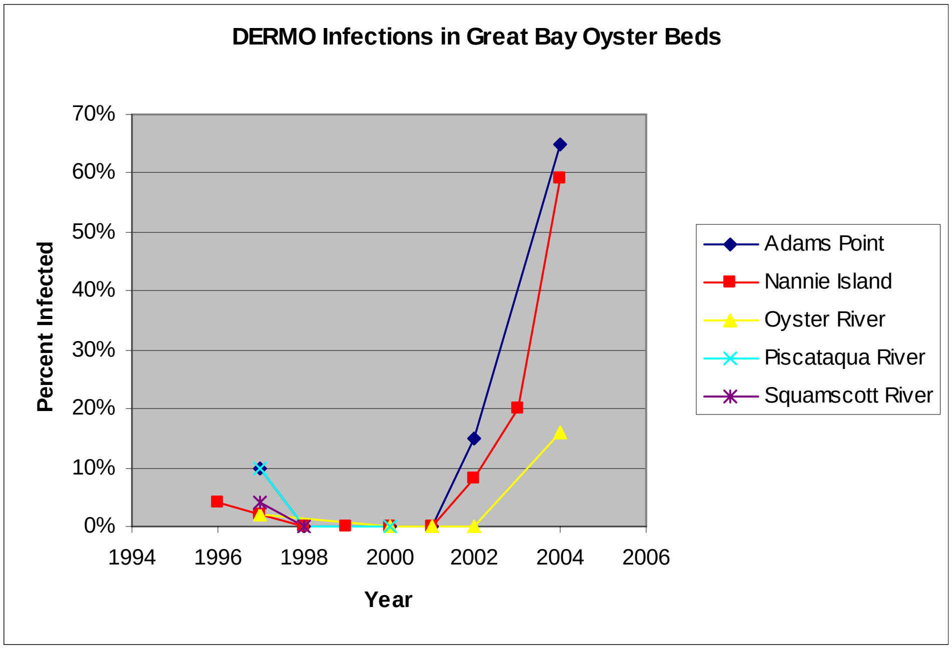
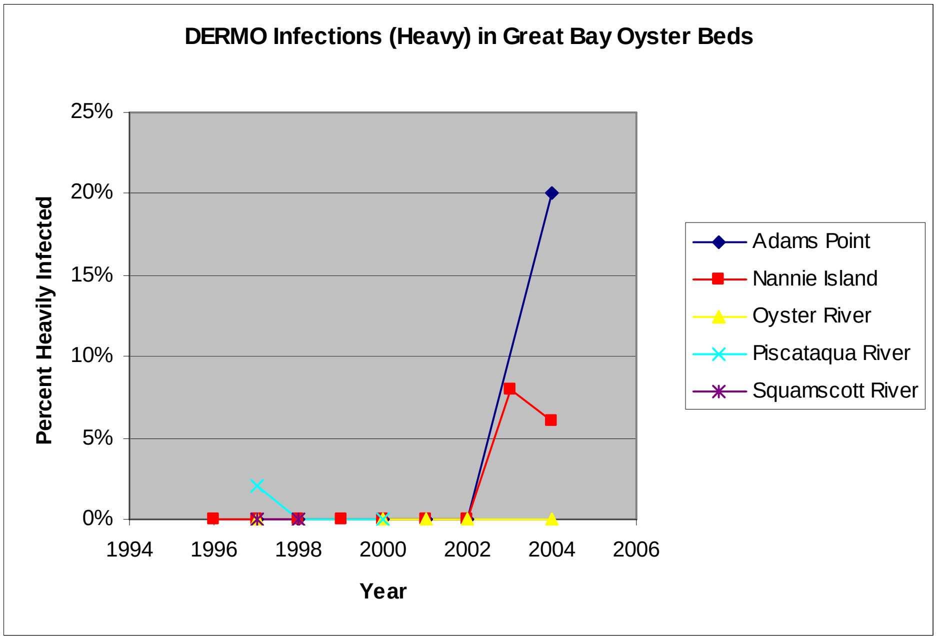


Figure 24: Prevalence of heavy Dermo infection in Great Bay oysters



SHL12 - PREVALENCE OF CLAM DISEASE

Monitoring Objective

The objective of this supporting variable is to estimate the prevalence of the clam disease sarcomastous neoplasia. This information is needed to answer the following monitoring question:

"Has the incidence of shellfish diseases changed significantly over time?"

Measurable Goal

This is a supporting variable so no measurable goal has been established. These data are collected to provide additional information to help interpret the results of other indicators.

Data Analysis and Statistical Methods

The average prevalence of neoplasia infection (both total and heavily infected) is tracked over time. No statistical tests are applied.

Results

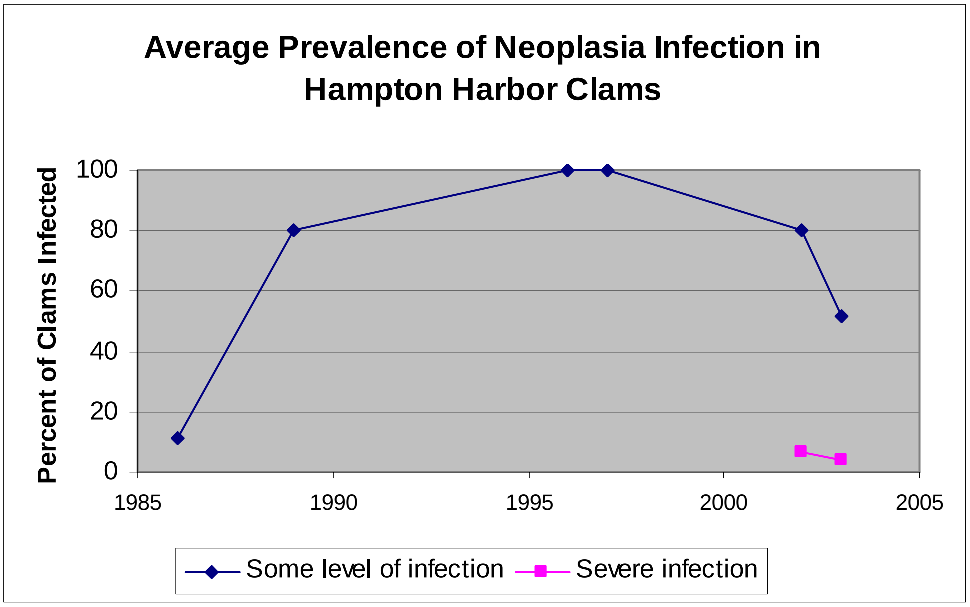
Sarcomatous neoplasia (neoplasia) is a lethal form of leukemia in soft-shell clams. In 1986-1987, neoplasia was first discovered in clams from Hampton Harbor. The incidence of neoplasia in clams from the Common Island, Confluence and Middle Ground flats were 6%, 27%, and 0% respectively. By 1989, 80% of the clams from the Confluence flat had neoplastic cells. In 1996 and 1997, 100% of the clams collected from each flat had neoplastic cells (FPL, 2004).

In 1999, the screening process for neoplasia in the Seabrook Station monitoring program was changed. Instead of reporting the percentage of clams with neoplastic cells, Seabrook Station began reporting the percentage of clams where 100% of the cells were neoplastic. The survey conducted in July 1999 indicated that the percentage of clams with 100% neoplastic cells ranged from 2.4% to 7.0% at all flats except Middle Ground where no clams with 100% neoplastic cells were detected (FPL, 2004).

In 2002 and 2003, the prevalence of different degrees of neoplasia were measured by UNH for Seabrook Station (FPL, 2003, 2004). The results show that approximately 80% and 50% of the clams had some degree of infection in 2002 and 2003, respectively. The percent of clams with 76-100% neoplastic cells in 2002 and 2003 was similar to the results from 1999, 3-9% and 0-7%, respectively.

Figure 23 shows the trend in total neoplasia prevalence over time. Following its first detection in 1986, neoplasia has infected at least 50% of the clams. The disease is normally fatal in clams, although some lightly infected clams can recover (Brousseau and Baglivo, 1991). Clams with a high degree of infection (90-100% neoplastic cells) are expected to have a 92% mortality rate (Farley, 1989). Therefore, at least 5% of the adult clams in Hampton Harbor are lost to this disease each year.

Figure 25: Average prevalence of neoplasia infection in Hampton Harbor clams



SUMMARY

While it is difficult to summarize the overall conditions in New Hampshire's estuaries, the indicators of shellfish resources presented in this report show that:

- Both the oyster and clam populations are at or are approaching their lowest values in the historical record. Harvestable oyster standing stock in 2004 was only 11% of the NHEP goal of 50,000 bushels and 5% of the maximum observed standing stock in 1993. Moreover, historical records indicate that much of the oyster fishery had already been lost before 1993 (Jackson, 1944). Harvestable clam standing stock in 2003 was close to the historical lows observed during crashes of the fishery in 1978 and 1987. Trends over time indicate that the clam populations have followed a cyclical pattern of boom and bust. In contrast, the oyster populations appear to be experiencing a slow decline.

- Oyster and clam populations are plagued by persistent diseases and predation. Between 4 and 20 percent of the oysters in Great Bay and clams in Hampton Harbor are heavily infected by protozoan pathogens or sarcomatous neoplasia (a form of leukemia), respectively. Green crab populations in Hampton Harbor, which prey on juvenile clams, have fluctuated over the past 27 years but no long-term trend is evident. The green crab is an invasive species which was introduced from Europe and currently exists along the Atlantic coast from Nova Scotia to Delaware.

- The number of people taking part in recreational shellfishing activity is decreasing. Oyster and clam harvesting license sales have steadily fallen since the 1980s. The current number of license holders is approximately 12% of the number from license holders in 1981.

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